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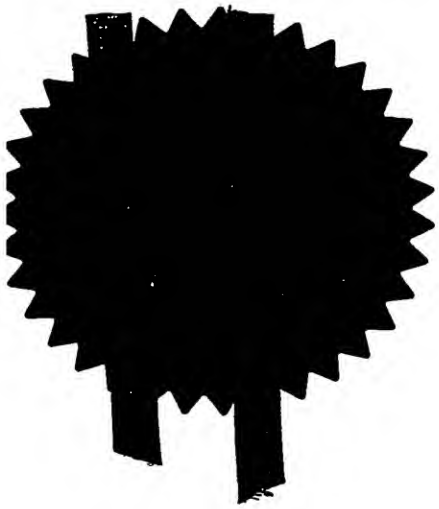
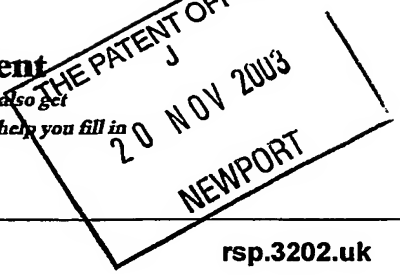


Signed

Dated 4 January 2005

Patents Form 1/77

nts Act 1977
ule 16)



1/77

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

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1. Your reference — rsp.3202.uk

2. Patent application number *(The Patent Office will fill this part in)* — 0327021.2

20NOV03 E953754-1 D10002
1/7700 0.00-0327021.2

20 NOV 2003

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

Red Spider Technology Limited
Westhill Business Centre
Arnhall Business Park
Westhill
Aberdeen
AB32 6UF
United Kingdom

Patents ADP number *(if you know it)* 87517940001

If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention

Improved valve

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

Kennedys Patent Agency Limited
Floor 5, Queens House
29 St Vincent Place
Glasgow
G1 2DT

Patents ADP number *(if you know it)* 0805 824 0002

6. Priority: Complete this section if you are declaring priority from one or more earlier patent applications, filed in the last 12 months.

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. Divisionals, etc: Complete this section only if this application is a divisional application or resulted from an entitlement dispute (see note f)

Number of earlier UK application	Date of filing *(day / month / year)*

8. Is a Patents Form 7/77 (Statement of inventorship and of right to grant of a patent) required in support of this request?

Answer YES if:

a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.

Otherwise answer NO (See note d)

YES

Patents Form 1/77

9. Accompanying documents: A patent application must include a description of the invention. Not counting duplicates, please enter the number of pages of each item accompanying this form:

Continuation sheets of this form	
Description	17
Claim(s)	
Abstract	
Drawing(s)	7

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent (Patents Form 7/77)	
Request for a preliminary examination and search (Patents Form 9/77)	
Request for a substantive examination (Patents Form 10/77)	
Any other documents (please specify)	

11. I/We request the grant of a patent on the basis of this application.

Signature(s) Kennedys KENNEDYS PATENT AGENCY LTD Date 19.11.03

12. Name, daytime telephone number and e-mail address, if any, of person to contact in the United Kingdom

Arlene Campbell Tel: 0141 226 6826

Warning

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Notes

a) If you need help to fill in this form or you have any questions, please contact the Patent Office on 08459 500505.

b) Write your answers in capital letters using black ink or you may type them.

c) If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.

d) If you have answered YES in part 8, a Patents Form 7/77 will need to be filed.

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f) Part 7 should only be completed when a divisional application is being made under section 15(4), or when an application is being made under section 8(3), 12(6) or 37(4) following an entitlement dispute. By completing part 7 you are requesting that this application takes the same filing date as an earlier UK application. If you want the new application to have the same priority date(s) as the earlier UK application, you should also complete part 6 with the priority details.

Improved Valve

The present invention relates to valves typically used on downhole tools in oil and gas wells and in particular, though not exclusively, to a water injection valve.

In secondary recovery of oil and gas wells it is possible to use the technique of water flooding for enhanced oil recovery. This technique relies on injecting water into the reservoir and is normally undertaken using one or more water injection wells. Such valves are typically made up to a wireline lock or retrievable bridge plug and run to depth, usually in the packer tail pipe. A suitable valve design comprises a body having one or more ports which include seat(s) against which a poppet or other closing surface of the valve can rest. The poppet is biased towards the seat(s) to block of the ports and hold the valve in a closed position. Water passed down the tubing string of a well bore will arrive at the poppet, seated in a closed position. Water pressure will work against the loading of the spring and force the poppet away from the seat. This exposes the ports and thus water is ejected from the body of the tool to the

annulus between the tool and the well bore for injecting into a formation.

Such valves have a number of disadvantages. Typically these valves have a spring which applies a load to the poppet to keep the valve closed. Thus when water flows an initial pressure will open the valve but there is a tendency for the valve to close again as the pressure drops when the fluid is flowing through the valve.

Some water injection valves are designed as high lift valves. Such valves are designed so that the poppet moves easily to the full open position with the minimum water injection flow rate. Unfortunately such a high lift design results in a low load spring design producing low resultant closing forces on the poppet mechanism. This can lead to problems with debris ingress between the poppet and seat preventing a seal.

A further disadvantage of these valves is in the arrangement of the ports through which the water flows when the valve is open. By the nature of the design, these ports are typically small in diameter and as such they increase the pressure drop through the valve, cause erosional problems through the valve and increase the potential debris build up at these ports.

It is an object of at least one embodiment of the present invention to provide a valve which overcomes at least some of the disadvantages of prior art valves.

It is a further object of at least one embodiment of the present invention to provide a water injection valve which is a high lift valve.

A yet further object of at least one embodiment of the present invention is to provide a water injection valve having a high bypass flow area.

According to a first aspect of the present invention there is provided a valve for use in a downhole tool, the valve comprising first and second sealing surfaces moveable with respect to each other to create a passage therebetween, the first surface being moved by biasing means toward the second surface and characterised in that a load adjuster is located between the biasing means and the first surface to vary the load applied by the first surface upon the second surface.

In a typical valve, as the first surface approaches the second surface to move the valve to the closed position, the load from the biasing means is at its lowest and the potential for debris build-up between the surfaces is at its highest. By incorporating a load adjuster, the load can be increased as the valve is closed, to pull the valve to the fully closed position. This increases the surface to surface contact load and resulting sealing performance of the valve.

Preferably the biasing means is a spring. More preferably the biasing means is arranged on a central axis of the valve.

Preferably the load adjuster comprises a sprung collet. The sprung collet may comprise an engaging portion having sprung cantilevers extending therefrom. The engaging portion may be considered as a dog. Preferably the collet is arranged in parallel to the central axis.

Preferably the load adjuster further includes at least one roller. Preferably at least one roller is mounted on the engaging portion or dog.

Preferably the roller is located against a running surface of the valve wherein the running surface is substantially parallel to the central axis. More preferably the running surface comprises three sloping sections, a first sloping section being at a first angle to the running surface, a third sloping surface being at a second angle to the running surface and an apex of the first sloping surface being connected to the base of the third surface to provide the second sloping surface.

In an embodiment of the present invention the first and third sloping surfaces are angled at approximately ninety degrees to the running surface. In an alternative embodiment of the present invention the first and third sloping surfaces are at a steep angle to the running surface.

Preferably the valve comprises a first substantially tubular body having a second substantially tubular body located therein. Preferably also the second tubular body includes the first sealing surface while the first tubular body includes the second sealing surface.

Preferably the first sealing surface is an outer surface of a poppet located at an end of the second tubular body. Preferably the second sealing surface is a seat located circumferentially on an inner surface of the first tubular body.

Preferably biasing means is provided in the second tubular body. Advantageously the biasing means is a spring located centrally within a bore of the second tubular body.

Preferably a first end of the spring locates at a base of the second tubular body while a first end of the spring locates at a base of the poppet. Preferably the poppet is arranged to slide on an outer surface of the second tubular body.

More preferably the load adjuster is arranged on an inner surface of the poppet and the running surface is arranged on an outer surface of the second tubular body. In this way biasing of the spring causes movement of the load adjuster along the outer surface of the second tubular body. In a preferred embodiment the sprung collet ensures that the roller is located against a sloping surface of the running surface when the tool is assembled.

Advantageously the first tubular body includes a plurality of ports located thereon. Preferably the ports are arranged circumferentially on the first tubular body. More preferably the cross-sectional area of the ports is greater than half the total surface area of the first tubular body. In a preferred embodiment there are two

rectangular ports located on the first tubular body. The ports are arranged such that they take up a substantial portion of the tubular body to provide for maximum flow through of fluid when the valve is open. In the preferred embodiment portions of the tubular body between the ports provide longitudinally arranged rails.

Preferably the outer surface of the poppet engages with the rails to maintain linear movement of the poppet within the first tubular body.

Preferably the valve is an injection valve. The valve may be a water or gas injection valve. Alternatively the valve is a check valve as would be used in a downhole safety device.

While the terms 'up', 'down', 'top' and 'bottom' are used within the specification, they should be considered as no more than relative, as the valve of the present invention may be used in any orientation.

An embodiment of the invention will now be described by way of example only with reference to the accompanying figures in which:

Figure 1 is a part cut-away cross-sectional view through a valve according to an embodiment of the present invention;

Figures 2 (a) and (b) are schematic illustrations of the position of the poppet seat and poppet when the valve of Figure 1 is moved to the closed position;

Figure 3 is a cross-sectional view of the valve of Figure 1 divided in two parts wherein the left hand side of the figure illustrates the valve in the open configuration and the right hand side illustrates the valve in the closed configuration;

Figure 4 is a plot of valve closing characteristics comparing the spring load on a traditional injection valve against that of an injection valve according to the present invention; and

Figures 5 illustrate a schematic view of the arrangement of the flow housing on the valve of Figure 1 wherein Figures 5 (a),(b) are rotated by ninety degrees with respect to Figures (c),(d).

Referring initially to Figure 1 of the drawings there is illustrated a valve, generally indicated by reference numeral 10, according to a first embodiment of the present invention. Figure 1(a) is a top section of the valve 10, while Figure 1(b) is a lower section of the valve 10. To those skilled in the art, valve 10 is recognisable as a water injection valve but could equally be adapted to a check valve or other arrangement as would be found on a downhole tool for controlling fluid flow.

Valve 10 comprises a top sub 12 including a box section 14 for connecting the valve 10 to an anchoring device i.e. a lock or bridge plug. Typically the valve is made up to an wireline lock or retrievable bridge plug and run to depth, usually in the packer tail pipe. Threaded to the top sub 12 is a flow housing 18. The design of flow housing 18 is advantageous to the operation of the

injection valve and will be described hereinafter with reference to Figures 5. The housing 18 is primarily a tubular body providing an outer surface 20 to the valve 10. At a lower end 22 of the housing 18 is attached a bottom sub or end cap 24. End cap 24 is threaded to the housing 18 and prevented from detachment by means of set screws 26. There is also located an adjustment nut 28 and an adjacent lock nut 30 so that the relative positioning between end cap 24 and the housing 18 can be set.

End cap 24 includes a bore 32 into which is located a inner tube 34. Inner tube 34 provides a tubular body having an inner cylindrical surface 36 and an outer surface 38. Mounted within the inner cylindrical surface and abutting a base 40 of the bore 32 is a spring 42. Spring 42 extends beyond the upper end 46 of the inner tube 34.

From the end 46, the outer surface 38 provides a substantially longitudinal portion 48, running in parallel to the spring 42 which is aligned on a central axis 50 of the valve 10. Portion 48 meets a face 52 which rises outwardly from the surface 38 at an angle of approximately seventy-five degrees. This provides an acute ramp on the outer surface 38. Thereafter the outer surface provides a gentle ramp 56 toward a second face 54 which provides a second acute face as that of the face 52. Between each face 52,54 the outer surface 38 the gentle ramp 56 extends from the apex 60 of the face 52 to the base 62 of the face 54. This ramp 56 is directed toward the central axis 50 as it travels toward the end cap 24.

Located below the face 54 are the end portions of a first collet spring 66 and a poppet skirt 68. The collet spring 66 and the poppet skirt 68 are threaded together and locked by set screws 64. The collet spring 66 and the poppet skirt 68 can slide on the outer surface 38 of the inner tube 34.

Collet spring 66 extends toward the upper end 70 of the valve 10 providing a cantilevered release spring terminating at a dog 72. Dog 72 is a typical dog providing inner 74 and outer 76 raised portions. Although only one dog 72 is illustrated, it will be appreciated that any number can be arranged around the inner tube 34 Dog 72 is connected to a further collet spring 78 whose end 80 extends toward the upper end 70 of the valve 10. The collection of collet spring 78, dog 72 and collet spring 66 'fingers' provide a collet generally indicated by reference numeral 100.

Typically, the collet 100 is formed by turning a profile onto a cylinder and then milling parallel slots through the cylinder axially within its length. The amount of parallel slots arranged around the circumference equals the number of fingers (collet spring 78, dog 72 and collet spring 66). The fingers act like a beam supported at each end. End 80 of collet 100 is cylindrical and supported within a corresponding cylindrical inner surface 82 of a poppet 84.

The poppet skirt 68 is threaded and held by set screws 86 to a recess 88 on an outer surface 90 of the poppet 84. Located above the collet spring 78 on the poppet 84 is a spring washer 92. Spring washer 92 includes an inner lip

94 arranged to face the end cap 24 and retain a top end 96 of the spring 42.

Mounted upon the dog 72 is a wheel 102 arranged so that it can ride upon the outer surface 38 of the inner tube 34. Indeed the wheel 102 may locate on the face 52, run along the ramp 56 towards face 54 as described hereinafter with reference to the accompanying figures. An end 69 of the skirt 68 meets an inner surface 71 of the flow housing 18. An end 69 Spring 42 is thus contained between a base 40 of the end cap 24 and the lip 94 of the spring washer 92 and its movement is controlled by the movement of the collet 100 in relation to the outer surface 38 of the inner tube 34.

The poppet 84 provides a rounded nose cone 104 which locates in a bore 106 on the top sub 12. Poppet 84 further provides a frusto-conical surface 108 which includes a ledge 110 which provides a sealing surface 111 to seal against a poppet seat 112 located on the flow housing 18. Poppet seat 112 provides a further sealing surface 113 which when it meets the surface 112 seals the bore 106 to prevent fluid flow which enters the bore 106 from exiting the valve 10. This configuration can therefore be considered as a closed configuration of the valve 10. Appropriate O-rings 114a and 114b are located between the poppet seat 112 and the inner surface 116 of the flow housing 18, and between the top sub 12 and the flow housing 18, respectively. This prevents the ingress of fluid through the valve 10.

The ledge 110 and thus the poppet 84 is held against the poppet seat 112 initially by the spring 42 and further by

the collet 100 when the dog 72 is located at the face 52 and the wheel 102 abuts the face 52.

This closed position is further illustrated with the aid of Figures 2. In Figure 2(a) the wheel 102 is located at the apex 60 of the face 52. At this position the poppet seat 112 and the poppet 84 are close to touching. This is the location that a typical water injection valve of the prior art would find its spring load at its lowest and the potential for debris problems are at their highest. At this position the collet 100 and in particular the collet springs 66, 78 take over from the spring 42 and drive the poppet 84 to the fully seated position against the poppet seat 112. As this occurs the wheel 102 runs down the acute face 52 and locates there against. The poppet seat 112 is now located within the ledge 110 of the poppet 84 and the surfaces 111,113 seal together.

In this position the collet 100 preloads the poppet 84 against the poppet seat 112. Thus the collet 100 has pulled the valve to the fully closed position. This increases poppet 84 to seat 112 contact load and enhances the resultant sealing performance of the valve.

This closed position is shown on the right hand side of Figure 3 wherein the poppet 84 is seated on the poppet seat 112 and there is no flow through the valve. In order to initiate flow through the valve, water or other fluid is passed through the bore 106. Water causes a pressure on the nose 104 of the poppet 84 and pushes it towards the end cap 24.

Opening of the valve occurs as poppet 84 moves downwards as shown on the left hand side of Figure 3. As it moves downwards a flow passage 120 is uncovered through the housing 18. On depression of the poppet 84, the wheel 102 is caused to ride up the face 52. The seal between the surfaces 111,113 is broken. Due to the close fit between the ledge 110 and the seat 112, the load due to the, now leaking, pressure will be sufficient to allow the wheel 102 to reach the apex 60. Once over the apex 60 the wheel runs rapidly down the ramp 56 towards the face 54. An end 69 of the poppet skirt 68 meets an inner surface 71 of the flow housing 18. Once the dog 72 has been pushed out of the groove provided by face 52 on valve opening, the drag friction from the collet 100 has been minimised so this does not detract from the spring 42 return load.

Thus when the valve is opened, the valve operates as a high lift valve. This means the poppet 84 moves easily to the full open position with minimal water injection flow rate. Use of the high lift design minimises potential for debris build up above the valve at the location of the seat 112 in the top sub 12.

Reference is now made to Figure 4 of the drawings which is a plot of valve position 122 between the open and closed configuration against spring load on the poppet 84. Two graphs are provided. The first 126 shows a typical injection valve load characteristic for prior art injection valves. In this configuration it is seen that the load follows a straight line from a high spring load 125 when the valve is fully open, down to a lower value 123 when the valve is closed. This is a linear

relationship. Valve 128 illustrates the valve load characteristics of a valve according to the present invention. The initial loading at valve open is similar to that of the traditional valve 126. It follows the same linear downward path until just before the valve is closed at position 130. As the valve is closed an additional load is generated by the collet springs 66, 78 and as a result the graph rises sharply to a value 127 which may be considerably larger than the value of the spring load of the traditional valve in the closed configuration.

Returning to Figure 3, there is illustrated a poppet skirt 68. Poppet skirt 68 is threaded to the recess 88 on the poppet 84. The skirt 68 provides a streamlined profile running back to the threads 64 which attach it to the collet 100. Such a profile of the nose 104 together with the skirt 68 provides a streamlined flow passage 120 to maximise fluid flow through the valve in the open position. This is further enhanced by the design of the flow housing 18 located around the inner tube 34. This is seen with the aid of Figure 5.

Figures 5 (a) and (b) provide a side view of the housing 18, while Figures 5(c) and 5(d) are of the same housing rotated by 90 degrees. Flow housing 18 comprises a tubular body 130 which has a diameter equal to the diameter of the top sub 12 beside the sub 12. Oppositely arranged on the body 130 are two slots or ports 132. Ports 132 are arranged longitudinally and cover a substantial portion of the valve 10, beginning at the top sub 12 and ending near the end cap 24. Ports 132 are substantially rectangular in cross-section having a

rounded portion 134 toward the end cap 24. The ports 134 may be of any chosen dimensions. The shape in this embodiment is as a consequence of milling through a cylinder formed on a slope. Together the ports 132 remove a substantial portion of the body 130 to provide maximum flow of fluid through the valve 10. Portions of the body 30 remaining to either side of the ports 132 provide rails 136 illustrated in Figures 5(c) and 5(d). The rails help guide the poppet 84 through the valve without impeding its path. Thus as can be seen from Figures 5(a) and 5(b), the poppet 84 and poppet skirt 68 are substantially exposed within the body 130.

This cut-away to flow housing 18 results in the valve 10 having a high bypass flow area which minimises the pressure drop and erosion problems through the valve 10. This additionally reduces the debris build up potential.

Where high injection rates and/or the potential for a highly debris laden environment are anticipated, then the addition of a debris skirt can be made. This skirt will reduce the flow area through the valve however.

It is also noted that the collet 100 is located within a "dead area" of the valve 10 where fluid flow is not experienced and this minimises the effects to the flow and keeps it away from any debris passing through the valve 10.

In an alternative embodiment, the areas of the valve 10 which are exposed to the injection flow rates such as the nose cone 104 and surfaces of the flow housing 18, may be coated with a tungsten carbide based coating. The

coating is directed to areas where the direction of flow changes in particular. The coating is included to help protect the valve sealing surfaces from the effects of erosional flow particularly when large amounts of debris are anticipated. Such coatings are known to those skilled in the art of downhole ball valve technology.

In an alternative embodiment of the present invention, the poppet seat 112 is made reversible which will help reduce valve redress costs. In a yet further embodiment, the poppet seat is provided as a soft seal. This embodiment is thus particularly suitable for applications where water and gas are injected alternately through the valve and the soft seal improves the gas sealing characteristics of the valve.

In use, valve 10 is run into a well bore typically made up to a wireline lock or a retrievable bridge plug, and run to depth in the closed configuration. Once in position, fluid to be injected through the valve 10 is introduced to the bore 106 at a suitable pressure. Fluid pressure exerted on the nose 104 of the poppet 84 acts against the spring 42. The poppet 84 is thus moved from sealing engagement with poppet seat 112 in a downwards relative direction. On opening, the wheel 102 of the collet 100 rides up the face 52 of the surface 38 and then runs down the ramp 56 towards face 54. An end 69 of the skirt 68 meets an inner surface 71 of the flow housing 18. The valve is now open. Flow rate through the valve is through bore 106 into flow ports 120 exiting through the ports 132 within the flow housing 18.

When the valve is to be closed, water pressure is reduced in the bore 106. Load from the spring 42 acts against the poppet 84 to move it back toward the poppet seat 112. Movement is effected relatively easily as the wheel 102 of the collet 100 moves up the ramp 56. When the wheel 102 reaches the apex 60 of the face 52 the collet springs 66, 78 take over from the spring 42 and drive the poppet 84 into the seated position against the poppet seat 112. Surfaces 111 and 113 abut to form a seal. In the fully seated position collet 100 preloads the poppet 84 as the wheel 102 is now located against the face 52.

The principle advantage of the present invention is that it provides a valve for a downhole tool in which the load upon the poppet can be maximised when the valve is closed and the poppet is seated against the poppet seat.

A further advantage of the present invention is that it provides an injection valve having a high bypass flow area which minimises pressure drop and erosion problems through the valve while also reducing debris build-up potential in the valve.

A yet further advantage of the present invention is that it provides an injection valve which is a high lift valve. By use of a collet, including a wheel, a poppet moves easily to the full open position with minimal injection flow rate applied.

It will be appreciated by those skilled in the art that modifications may be made to the invention herein described without departing from the scope thereof. For instance the number of dogs upon the collet may be varied

dependent on the adjustment to the load required in the design of the valve. Additionally though a poppet is shown, any suitable arrangement of two sealing surfaces could be used. Yet further the size and number of ports in the flow housing may be changed to vary the flow rate through the valve.

CUT AWAY SECTION SHOWING THE INJECTION VALVE
IN THE CLOSED POSITION

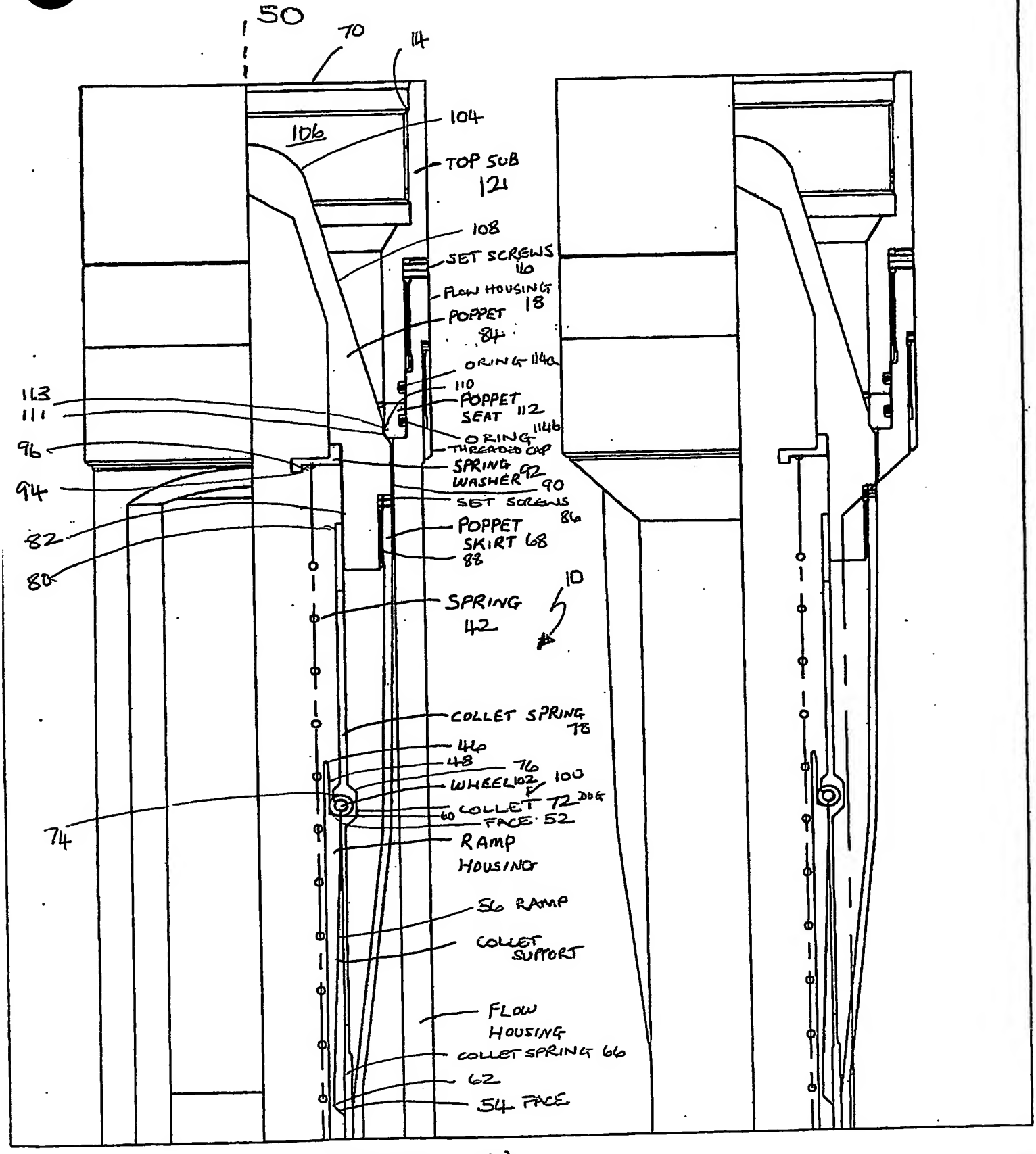

FIGURE 1(a)

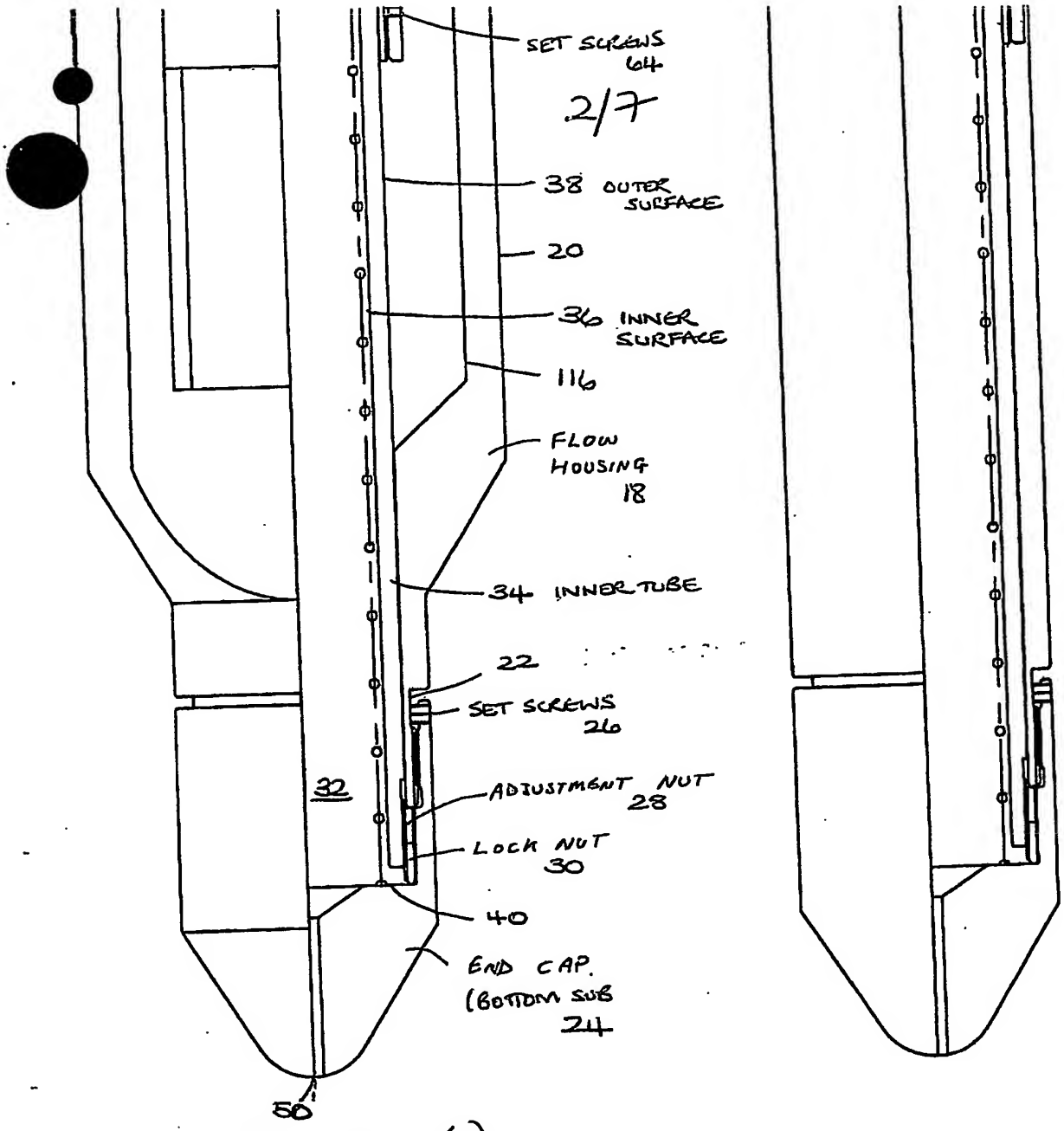
SET SCREWS
64
2/7
38 OUTER SURFACE
20
36 INNER SURFACE
116
FLOW HOUSING
18
34 INNER TUBE
22
SET SCREWS
26
32
ADJUSTMENT NUT
28
LOCK NUT
30
40
END CAP.
(BOTTOM SUB
24
50

FIGURE 1(b)

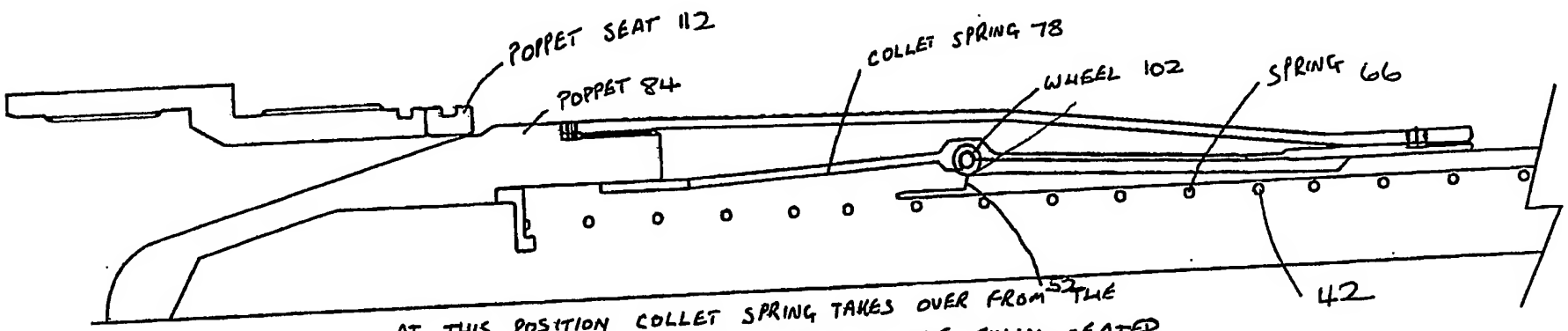

FIGURE 2(a)

AT THIS POSITION COLLET SPRING TAKES OVER FROM THE SPRING AND DRIVES THE POPPET TO THE FULLY SEATED POSITION

3/7

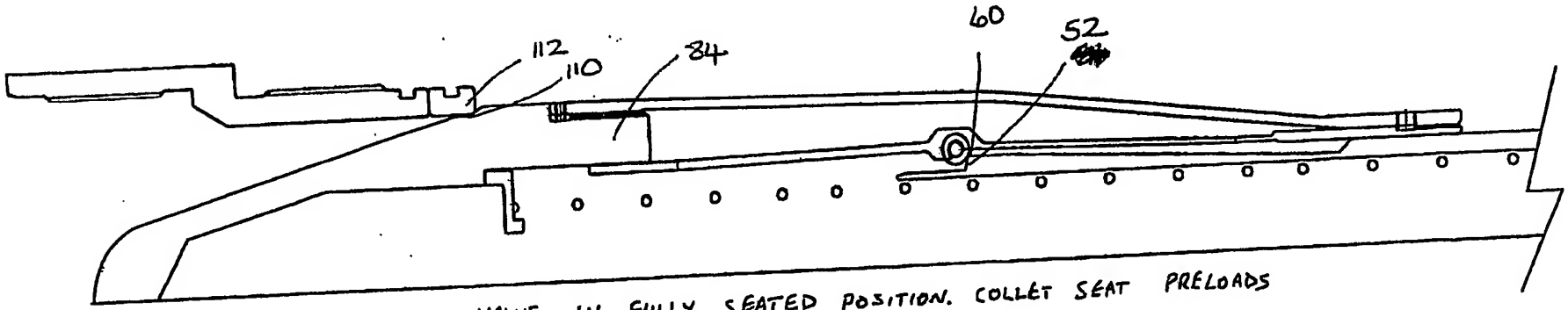

FIGURE 2(b)

VALVE IN FULLY SEATED POSITION. COLLET SEAT PRELOADS THE POPPET AGAINST THE POPPET SEAT.

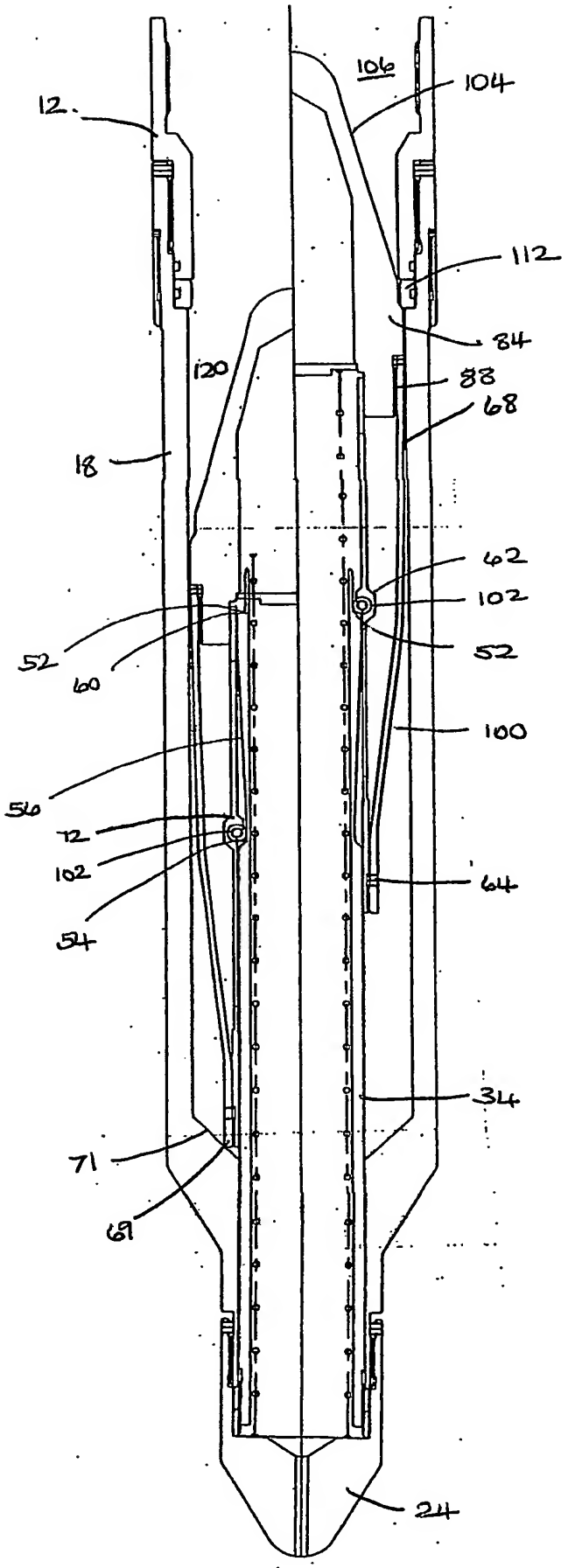
106
104
12
112
84
120
88
68
18
62
102
52
52
60
100
56
72
102
64
54
34
71
69
24

FIGURE 3

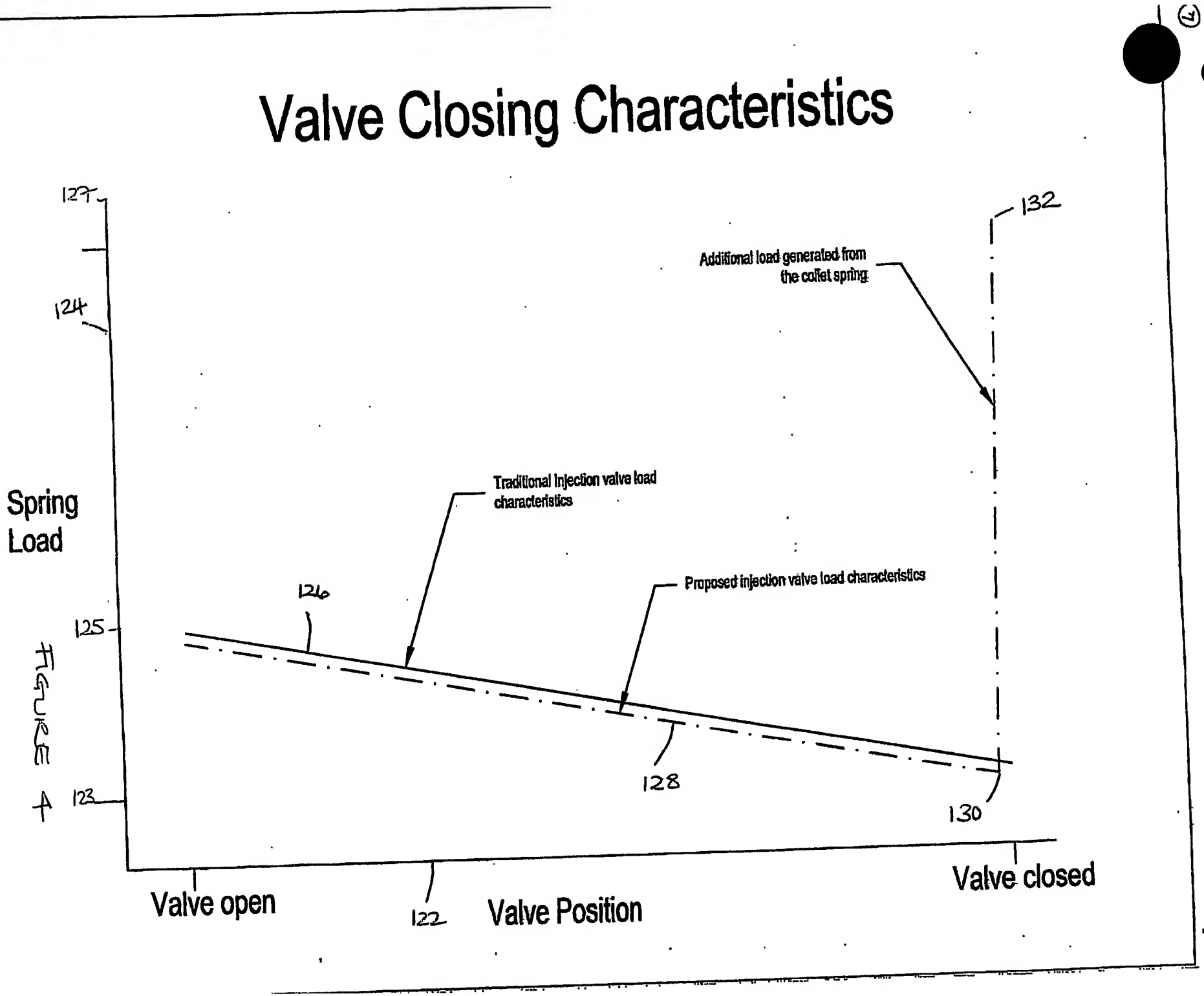
Valve Closing Characteristics
127
124
125
123
132
Additional load generated from the collet spring
Traditional Injection valve load characteristics
Proposed injection valve load characteristics
126
128
130
Spring Load
Valve open
122
Valve Position
Valve closed

FIGURE 4

5/7

INJECTION VALVE SHOWN IN THE OPEN POSITION.
(OUT. SIDE VIEW)

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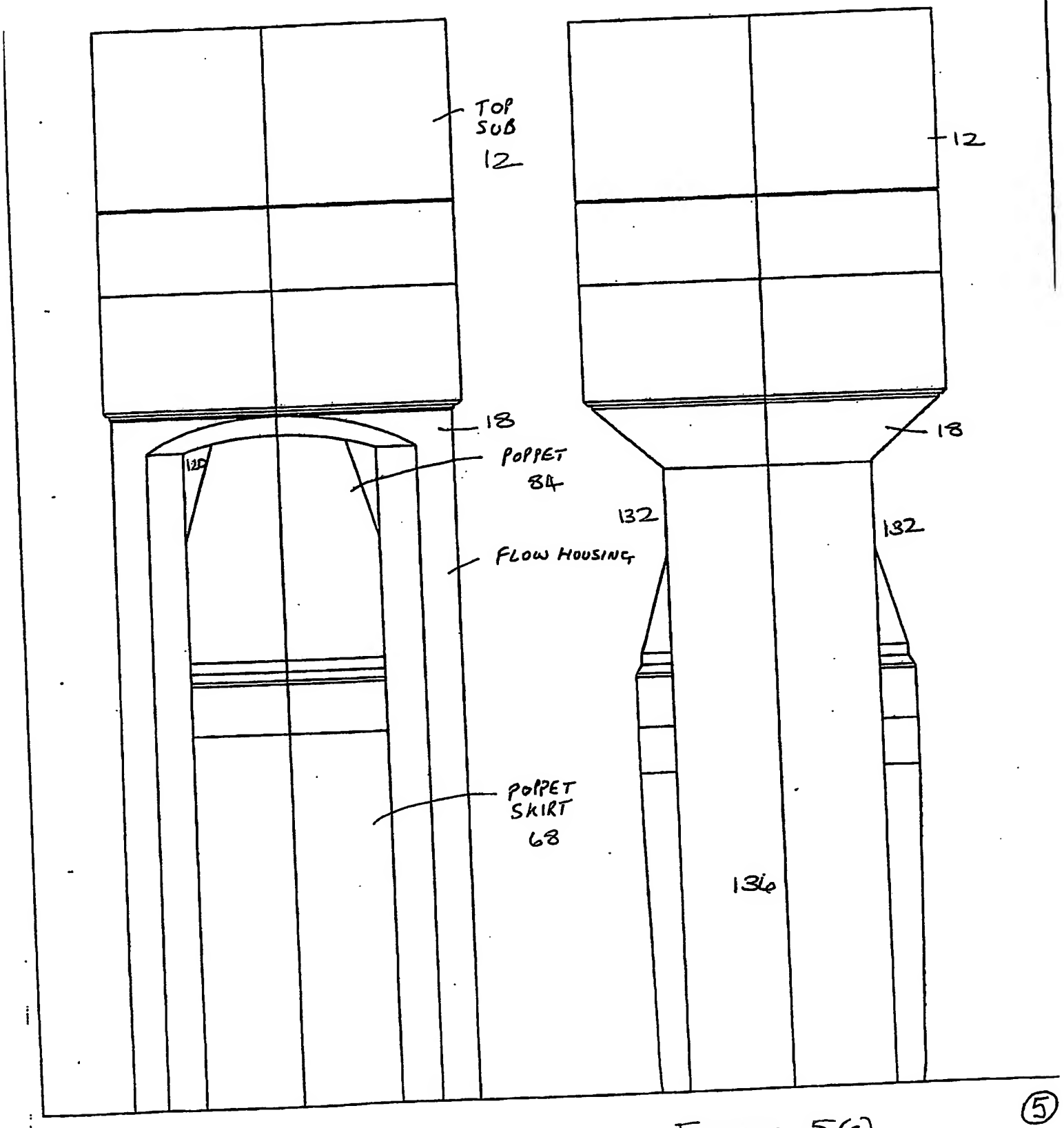

FIGURE 5(a)

FIGURE 5(c)

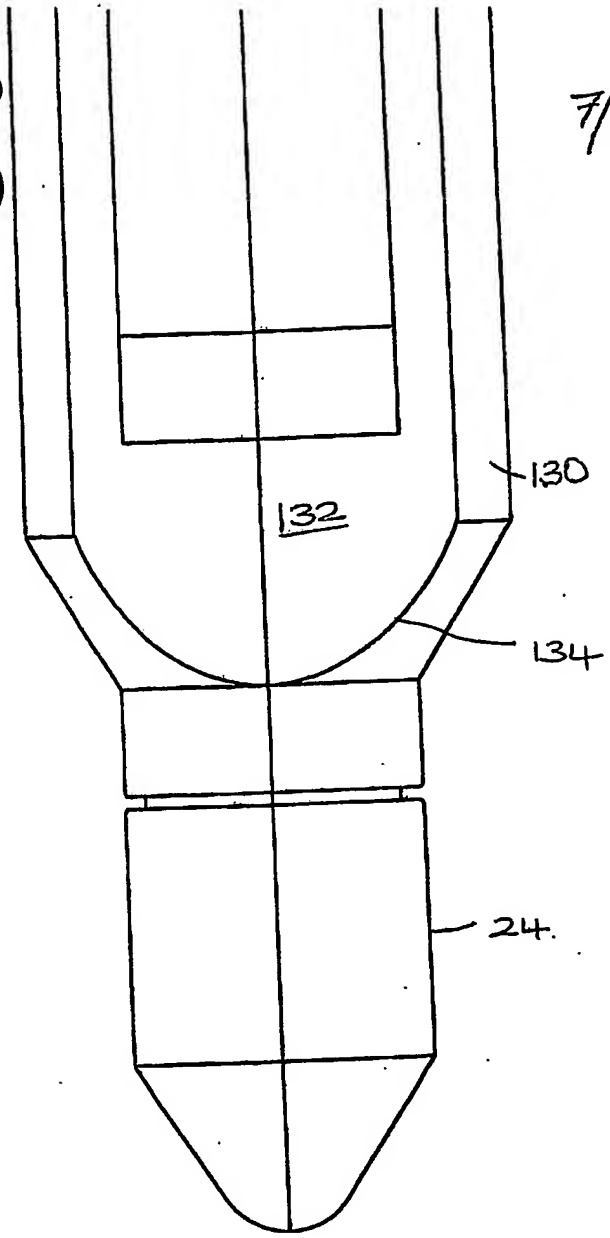

FIGURE 5(b)

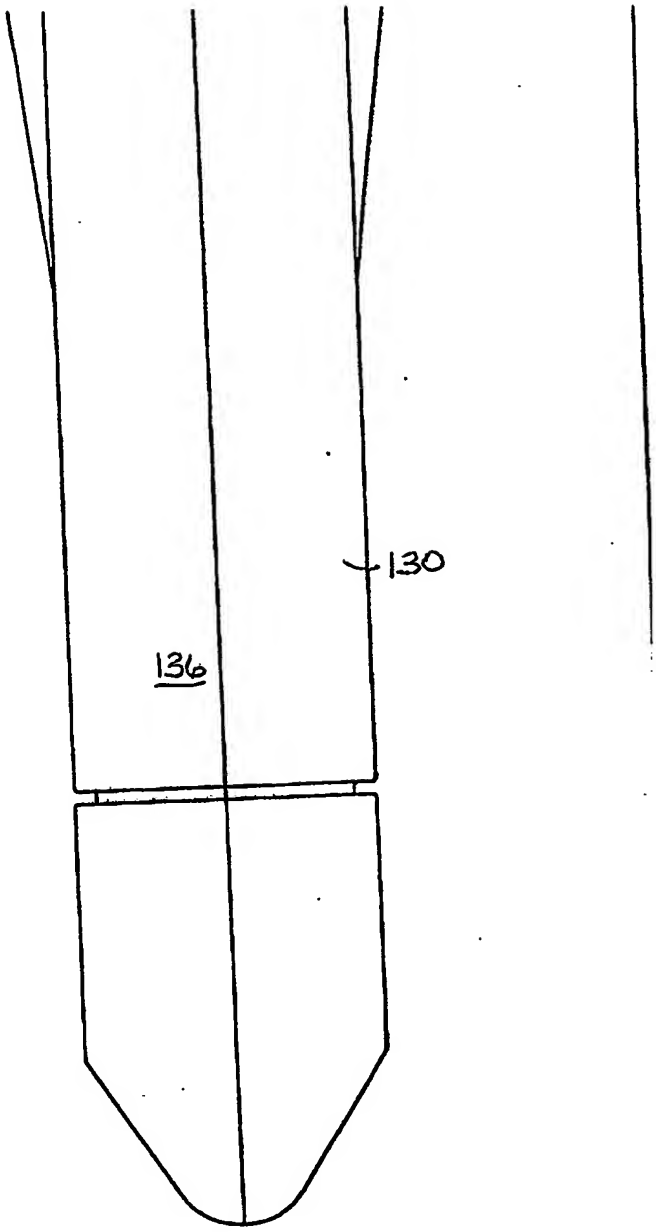

FIGURE 5(d)